

Earth Implementation Companion Note

Grid Management via Geometry – Practical Pathway for Existing Grids

Companion to: Grid Management via Geometry: A 2025 Framework for Phase-Coherent, Low-Entropy Grid Operation

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Author: Michael K. Nowlin

1. Purpose

This note translates the geometric framework into practical steps that utilities, system operators, and large industrial users can take on existing 2025 infrastructure. It is intentionally vendor-neutral and focused on actions that can be implemented with current tools such as SCADA, EMS, DMS, protection relays, and VFD drives. The goal is simple: reduce losses, heat, and nuisance disturbances by aligning grid operation with the three-phase geometry it was built on.

2. Core Concepts (One-Minute Summary)

- Symmetry is the asset: a three-phase system is most stable when its operation is symmetric and major control actions land close to the 0°, 120°, and 240° symmetry points.
- Misalignment has a measurable cost: when switching events occur at arbitrary angles, part of the energy is diverted into imbalance modes rather than useful work.
- Geometric loss law: $E_{\text{loss}} = k \cdot |\sin(\Delta\theta/2)|$, where $\Delta\theta$ is the misalignment between the switching instant and the nearest symmetry point and k depends on local impedance and event magnitude.
- Asymmetry metric: $\Delta_{\text{asym}} = \sqrt{I_0^2 + I_1^2 + I_2^2}$, which aggregates sequence components into a single scalar measure of geometric imbalance.

3. Implementation Overview – Five Workstreams

Implementation can start with one pilot feeder, one substation, or one plant. The work is organized into five parallel workstreams:

- Measurement & Baseline – quantify where you stand.
- Phase-Aligned Timing – adjust when major events happen.
- Grounding Geometry – treat grounding as a designed zero-sequence network.
- Customer / VFD Coordination – align large drives and motors with grid geometry.
- Monitoring & Feedback – track benefits and refine.

4. Workstream 1 – Measurement & Baseline

Objective: establish a measurable baseline for asymmetry and loss.

Actions:

- Identify 1–3 representative locations such as a transmission-to-distribution substation, an urban or industrial feeder, and a large customer facility with multiple VFDs.
- At each location, use existing tools to extract I0, I1, I2 from sequence component analysis; total current and I²R losses or proxy metrics from load-flow; transformer top-oil or hot-spot temperatures; and neutral-to-earth voltage where available.
- Compute and log $\Delta_{\text{asym}} = \sqrt{I_0^2 + I_1^2 + I_2^2}$ over time, along with the frequency and timing of major events such as tap changes, capacitor operations, breaker actions, and large load steps.
- Mark a baseline period (for example 30–90 days) and treat it as the “before geometric alignment” reference.

Deliverables: a simple table or dashboard showing average and peak Δ_{asym} , approximate I²R loss, and transformer temperature for the baseline period, plus a list of which devices are responsible for most of the large events.

5. Workstream 2 – Phase-Aligned Timing

Objective: move major events closer to symmetry points to reduce geometric loss.

Concept: define phase windows where switching actions are allowed or preferred and avoid having large events occur at arbitrary angles relative to the three-phase reference.

Actions:

- For a pilot substation or feeder, identify tap changers, capacitor banks, reactors, and large load steps.
- Using EMS/DMS or relay logic, implement simple timing rules so that tap changes and capacitor operations are grouped into short windows rather than scattered, and preferably occur during electrically quiet periods.
- In advanced phases, consider phase-angle-aware firmware or settings (where available) that approximate “phase windows” in terms of system state or synchronous reference.
- Re-measure Δ_{asym} , tap operation counts, and transformer temperature after changes are applied.

Expected outcomes (pilot scale): reduction in magnitude and frequency of negative- and zero-sequence currents, small but meaningful reductions in losses, and several degrees Celsius relief in transformer hot-spot under heavy loading.

6. Workstream 3 – Grounding Geometry

Objective: turn grounding from an incidental result of history into a conscious zero-sequence design.

Concept: zero-sequence current will use any path available, and today's paths are often the sum of decades of uncoordinated projects. Intentionally steering these currents reduces neutral-to-earth issues and hidden heating.

Actions:

- Map existing neutral and ground connections including transformer neutrals, station grounds, multi-grounded neutrals, and parallel metallic paths such as pipes, cable sheaths, and structural steel.
- Identify unnecessary or redundant neutral–earth bonds and locations where zero-sequence currents are clearly higher than needed.
- In consultation with protection and safety teams, designate a reduced set of primary reference points where the system ties firmly to earth and use delta–wye transformer banks strategically to steer zero-sequence currents away from sensitive assets.
- Re-measure I_0 at key buses, neutral-to-earth voltage, and related nuisance events such as false trips and unexplained heating.

Expected outcomes: reduced zero-sequence current and neutral-to-earth voltage, calmer and more predictable behavior during faults and switching, and less stress on particular transformers and neutrals.

7. Workstream 4 – Customer / VFD Coordination

Objective: align large customer drives and motors with grid geometry instead of against it.

Concept: VFDs and large motors are often individually tuned for process needs, not system coherence. Stepping and coordinating them reduces harmonic spread and asymmetry.

Actions:

- Identify one to three large customers willing to participate, such as plants with multiple 400–800 HP drives or facilities with frequent start/stop cycles.
- At the customer side, replace long arbitrary ramps with short stepped ramps (a few discrete speeds with dwell times) and, where feasible, align major step changes to quiet periods agreed with the utility.
- Monitor point-of-common-coupling currents and voltage during batch operations before and after changes, and track drive trips, flicker complaints, and local nuisance alarms.

Expected outcomes: lower peak inrush during coordinated starts, a narrower harmonic signature, reduced contribution to negative-sequence current, better plant power quality, and fewer disturbances on the shared feeder.

8. Workstream 5 – Monitoring & Feedback

Objective: turn initial pilots into a continuous improvement loop.

Key metrics include:

- Δ_{asym} and its trend over time.
- I^2R losses or proxy estimates from load-flow and transformer loading.
- Transformer hot-spot and top-oil temperatures.
- Neutral-to-earth voltage at critical points.
- Event logs such as trips, mis-operations, and alarms.

Actions:

- Build a simple dashboard or report that shows before-versus-after results for each pilot and highlights reductions in high-stress periods.
- Share results internally with protection engineering, operations planning, asset management, and customer relations teams.
- Identify which changes can be adopted system-wide by policy and where firmware or vendor cooperation could make geometric alignment easier.

9. Governance and Safety

All changes must respect existing safety codes and grounding standards, protection coordination and fault performance, and operational constraints and customer process needs. The geometric framework does not replace protection studies, short-circuit analysis, or equipment ratings; it sits on top of them, adding a geometric layer that helps reduce stress and entropy.

10. Summary for Decision-Makers

The framework does not require a new grid. It uses existing assets more intelligently through incremental, reversible, and measurable changes. Benefits include lower losses, cooler transformers, fewer neutral issues, and cleaner event logs, all achieved with tools already available in 2025 control rooms and plants.

The central claim is practical and falsifiable: a three-phase grid operated with explicit geometric discipline is more stable, more efficient, and less capital-intensive than the same grid operated without it. This companion note is a practical invitation to test that claim in the field.